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Short Communication

Airborne emissions of microplastic fibres from domestic laundry dryers

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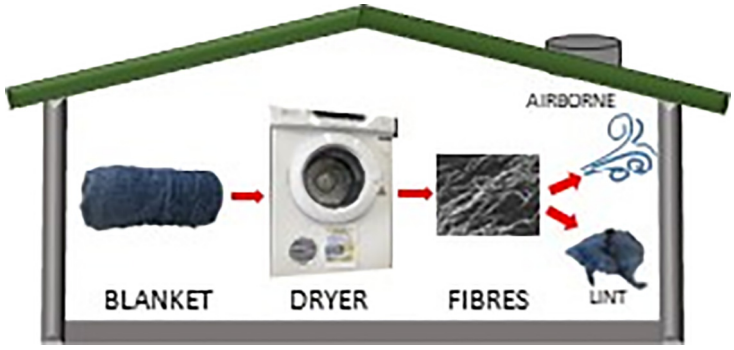
HIGHLIGHTS

- Emissions of microplastic fibres from residential dryers into air investigated.
- Mechanical drying of polyester emits microplastic fibres into the surrounding air.
- Over 20 mins operation, MP emissions for a 660 g blanket were ~ 1.6–1.8 fibres/m^3.
- Lint of 77 ± 22.4 mg ≈ 1.1 × 10^6 ± 3.2 × 10^5 fibres captured by inbuilt filtration.
- Lint emissions were approximately 0.012% of the blanket mass/wash.

GRAPHICAL ABSTRACT



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ABSTRACT

An emission source of microplastics into the environment is laundering synthetic textiles and clothing. Mechanical drying as a pathway for emitting microplastics, however, is poorly understood. In this study, emissions of microplastic fibres were sampled from a domestic vented dryer to assess whether mechanical drying of synthetic textiles releases microplastic fibres into the surrounding air or are captured by the inbuilt filtration system. A blue polyester fleece blanket was repeatedly washed and dried using the 'Normal Dry' program of a common domestic dryer operated at temperatures between 56 and 59 °C for 20 min. Microfibres in the ambient air and during operation of the dryer were sampled and analysed using microscopy for particle quantification and characterisation followed by Fourier-Transform Infrared Spectroscopy (FTIR) and Pyrolysis Gas Chromatography-Mass Spectrometry (Pyr-GC/MS) for chemical characterisation. Blue fibres averaged 6.4 ± 9.2 fibres in the room blank (0.17 ± 0.27 fibres/m^3), 8.8 ± 8.5 fibres (0.05 ± 0.05 fibres/m^3) in the procedural blank and 58 ± 60 (1.6 ± 1.8 fibres/m^3) in the sample. This is the first study to measure airborne emissions of microplastic fibres from mechanical drying, confirming that it is an emission source of microplastic fibres into air – particularly indoor air.

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1. Introduction

Microplastics are small pieces of synthetic polymers with their size commonly defined as being between 1 μm and 5 mm (Dris et al., 2016a, 2016b; Henry et al., 2019). While typically defined by the length of their longest dimension, microplastics have also been defined

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according to their diameter (Napper and Thompson, 2016) or ratio of dimensions (Obbard et al., 2014) for characterisation. Microplastic fibres have been reported as prevalent in all environmental compartments including atmospheric air and deposition (Cai et al., 2017; Dris et al., 2015; Dris et al., 2016a, 2016b), on beaches (Claessens et al., 2013), surface sea water (Cózar et al., 2014), the water column (Dai et al., 2018), marine sediments (Cole et al., 2011; Van Cauwenberghe et al., 2013), sea ice (Obbard et al., 2014), freshwater lakes (Eerkes-Medrano et al., n.d.; Eriksen et al., 2013; Gasperi et al., 2014), freshwater sediments (Horton et al., 2016; Klein et al., 2015) and soils (Hurley and Nizzetto, 2018; Nizzetto et al., 2016). Microplastic fibres have been detected in both urban (Dehghani et al., 2017; Dris et al., 2015; Dris et al., 2016a, 2016b) and remote regions (Allen et al., 2019; Free et al., 2014), including the Arctic (Lusher et al., 2015) and Antarctic (Cincinelli et al., 2017) and at high altitudes (Ambrosini et al., 2019) suggesting the capacity for long range atmospheric transport (Allen et al., 2019). Fibres are the most commonly identified microplastic shape reported in the gastrointestinal tracts of biota at all trophic levels; present within food (Barboza et al., 2018) and deposited onto food destined for human consumption (Catarino et al., 2018). Microplastic fibres have also been identified within the human lung (Pauly et al., 1998) and examined in simulated respiration models operated within indoor environments (Vianello et al., 2019), therefore, potentially posing a risk to human health through inhalation and ingestion exposure (Gasperi et al., 2018; Prata, 2018; Wright and Kelly, 2017).

Despite the environmental prevalence and research importance of microplastic fibres (Henry et al., 2019), little is known about their emission sources. Point source laundry emissions of wet lint from simulated industrial (Cocca et al., 2018; De Falco et al., 2018) and residential laundry effluent have been examined using laboratory based (Carney Almroth et al., 2018; Cocca et al., 2018; De Falco et al., 2018; Hernandez et al., 2017; Jönsson et al., 2018) and commercially available (Browne et al., 2011; Folko, 2015; Hartline et al., 2016; Karlsson, 2014; McIlwraith et al., 2019; Bruce et al., 2016; Pirc et al., 2016; Sillanpää and Sainio, 2017) laundering equipment. Early studies found that >1900 fibres are emitted per wash of a single blanket/fleece or shirt garment, equating to >100 fibres/L of captured laundry effluent (Browne et al., 2011). Subsequent research has calculated that each blanket releases approximately 1.1×10^5 fibres per wash (Carney Almroth et al., 2018). Total laundry emissions could release anywhere from 7×10^5 fibres per 6 kg load (Napper and Thompson, 2016) (1.16×10^5 fibres/kg) to between 6 and 17.7×10^6 fibres ($1.2–3.5 \times 10^6$ fibres/kg) based on 0.43 to 1.27 g lint weight from a 5 kg load (De Falco et al., 2018). Variability could be attributed to mesh sizes used in different studies, material composition, weave and fibre structure (De Falco et al., 2018), or the use or absence of chemical confirmation methods.

Despite previous studies identifying that laundering clothing is a significant point source for emissions of microplastics (Carney Almroth et al., 2018; De Falco et al., 2018; Hernandez et al., 2017; McIlwraith et al., 2019; Pirc et al., 2016; Salvador Cesa et al., 2017; Sillanpää and Sainio, 2017; Zambrano et al., 2019), as far as we are aware, only two studies have examined the process of mechanical drying of clothing and textiles. Limited to microfibre emissions captured within the internal filtration mechanisms (Pirc et al., 2016), one study established that mechanical drying resulted in greater microplastic emissions captured in emitted microfibres than fibres released into laundry effluent (Pirc et al., 2016). The second study examined laundering of clothing with wash and dry cycles, however dryer emissions were unreported (Zambrano et al., 2019). The hypothesis was that residential dryers contribute microplastic fibres into the surrounding atmospheric environment. The aim of the current study was to determine whether microplastic fibres are captured in inbuilt filtration or are emitted into the surrounding indoor/outdoor atmospheric environment during the mechanical drying of synthetic textiles.

2. Materials and methods

2.1. Sampling details

A blue coloured fleece blanket, labelled by the manufacturer as 100% polyester (fleece) and suitable for mechanical drying, was purchased from a prominent Australian retail outlet. The blanket, measuring 152 cm × 203 cm in size, was repeatedly laundered alone consecutively for five individual wash and dry cycles. Gravimetric analysis was conducted both prior to and post laundering cycles using a laboratory balance (Metter Toledo, New Classic MS Balance). The average (± standard deviation) of the dry blanket mass prior to and during consecutive laundry processing was 665 ± 6.73 g.

Laundering was performed within an 8 kg sensor washing machine (Bosch Australia, Clayton, VIC) using a standard 45-min-cycle at 40 °C and 1400 RPM. Samples were mechanically dried for 20 min using a 6.5 kg sensor dryer (Electrolux, Alexandria, NSW) representative of the Australian market. The dryer was operated using the 'Normal Dry' program described by the manufacturer as "suitable for everyday fabrics". Technical details of the drying program are unable to be provided by the manufacturer as the internal program varies the RPM and temperature automatically based on a combination of exhaust and ambient air temperature. However, internal maximum temperatures were monitored by using a temperature button (iTemperature, Instrument Choice) during operation both with and without a blanket, with temperatures ranging between 56 and 59 °C, achieved at approximately 10 min of dryer operation. The dryer was installed within a room approximately 21 m^3 in size, with no active ventilation. Access to the room during the sampling program was prevented to minimise air flow and potential contamination. The only air exchange occurred when opening and closing the door immediately prior to and post sampling.

2.1.1. Airborne particulate matter and inbuilt dryer filter sampling of polyester microfibres

Airborne particulate matter was sampled using a high volume total suspended particle air sampler (Komoto, Japan) with a sampling volume of 55 m^3/h to collect all airborne particles indiscriminate of size. Samples were collected onto a Whatman GF/A glass filter (1.6 μm), muffle furnaced at 450 °C for 4 h prior to use. Based on the extraction efficiency of the air sampler and room volume, sampling was limited to the first 20 min of dryer operation to avoid over sampling the air. Air samples were collected prior to the experiment as an ambient air room blank, during operation of the empty dryer as a procedural blank and whilst mechanically drying a blanket as five replicate samples ($n = 5$). Microfibres were collected by manually wiping the inbuilt dryer filter after procedural blanks and samples with paper towel, then stored wrapped in aluminium foil. At least ten minutes between each sample collection of air and lint was provided to allow time for deposition of resuspended particles (Cheng et al., 2016).

2.2. Microscopy

Analysis of the blanket, total particle count (fibres and fragments) and characterisation (colour, morphology and size) was undertaken using an Olympus SZ-CTV microscope coupled with a Motic Images Plus (Software Version 3.0) camera. To facilitate representative sub sampling, the samples (filters) from two room blanks, one procedural blank and one sample were divided into quarters and microscopically analysed separately to test homogeneity within the sample. Applying an ANOVA test to the null hypothesis that there was no variance between quarters for blue fibre count resulted in an f statistic of 0.173, with a significance of $p = .913$. A Brown-Forsyth test assessing homogeneity within the sample indicated a significance of $p = .912$ for blue fibres inferring moderate homogeneity between the quarters – both confirming the null hypothesis. Quartile analysis of the entire filter

was acceptable, consistent with the recommendation of Koelmans et al. (Koelmans et al., 2019). Quarter 3 (respective to sampler orientation) was selected for sub sampling as it demonstrated the least variability between sample types and replicates.

2.3. Chemical composition

2.3.1. Fourier-transform infrared spectroscopy (FTIR)

The blanket, both prior to and post laundering, and inbuilt dryer filter contents were characterised using Fourier-Transform Infrared Spectroscopy (FTIR) (Spectrum 2, Perkin Elmer) against a plastic specific spectral library (ATR Polymer Introductory Library, Perkin Elmer). After obtaining background spectra, samples were analysed in absorbance mode from 4000 cm^{-1} to 400 cm^{-1} at 300 scans/min, data interval of 0.2 cm^{-1} and resolution of 16 cm^{-1}. A random sub sample of larger visible blue fibres were manually extracted from the filter papers to examine for fibre composition analysis purposes to match to the blanket source. Identification was based on the library spectra with the highest percentage match to the sample. Only matches above 80% were used for positive identification.

2.3.2. Pyrolysis- gas chromatography -mass spectrometry (Pyr-GC/MS)

Pyrolysis gas chromatography mass spectrometry (Pyr-GC/MS) was used for chemical characterisation to verify the blanket material and assist in determining the composition of collected fibres.

Pyrolysis was undertaken using a multi-shot micro-furnace pyrolyser (EGA/PY-3030D) equipped with an auto sampler (AS-1020E) (Frontier Lab Ltd., Fukushima, Japan) coupled to a GC/MS – QP2010-Plus (Shimadzu Corporation, Japan). Being for identification and confirmation purposes only against the reference material of the blanket and PET analytical standard, the pyrolyser was operated in single shot mode. Based on the optimisation parameters in Okoffo et al. (Okoffo et al., 2020), the furnace was programmed to 650 °C with pyrolysis occurring for 12 s. The pyrolyser interface and GC injection port temperature was set at 300 °C with the samples injected at a split of 1:5 onto an Ultra Alloy® 5 capillary column (30 m, 0.25 mm I.D., 0.25 μm film thickness) (Frontier Lab). The GC oven temperature was held at 40 °C for 2 min, increased to 320 °C at 20 °C min^{-1}, then held for 14 min. Helium was used as a carrier gas at 1.0 mL/min with a constant linear velocity. The mass spectrometer was operated in full scan mode, acquiring data from 40 to 600 *m/z*, and the pyrogram was recorded from 2 to 30 min.

2.4. Statistical analysis

All quantification figures are based on a confidence interval of 95%, being ± two times the standard deviation of the mean calculated in Microsoft Excel version 16. Microscopy quantification from one quarter of the sample were extrapolated to the whole filter (number of fibres detected/m^3 based on Quarter 3 of the sample multiplied by 4) for whole of sample quantifications.

2.5. Contamination controls, QA/QC

2.5.1. Room control QA/QC

Efforts to reduce contamination were undertaken during all procedures. A restricted access room was utilised, cleaned thoroughly with Ethanol 70%, wiping all surfaces with paper towel and vacuuming the rubber floor twice two days prior to commencement. Access was prohibited during sampling episodes. However, contamination was possible through people entering the restricted room on days between sampling episodes; one small open but not operational air vent and an exposed section of 2.6 m × 0.15 m between the upper levels of the building which could have contributed particles to the results.

2.5.2. Sampling and storage QA/QC

Sampling and laboratory contamination controls included placing the sample blanket inside of a white cotton pillowcase when not in use and samples stored within aluminium foil. The samples were extracted from a new mechanical dryer, wiped clean with paper towel and Milli-Q water prior to each use (Napper and Thompson, 2016). The dryer was operated empty between the room blank and sample. The internal drum was also wiped clean with paper towel between replicates and the inbuilt dryer filter was wiped clean after each procedural blank and sample to remove potential carry over. Workspace controls included wiping all surrounding laboratory surfaces with Ethanol 70% and paper towel prior to use and operating without gloves where possible. Particle free gloves were used where necessary. Green cotton laboratory coats were worn and the clothing of attendees was noted during each sampling process. Subtraction was undertaken for any coloured fibre which was not blue, matching the blanket. The filter papers were stored within aluminium foil and during microscopy blank filter papers were exposed to determine whether baseline subtraction of laboratory contamination was required (Dris et al., 2016a, 2016b). Contamination mitigation for pyrolysis analysis included using new sample cups for each sample, collecting fibres using Ethanol 70% and MilliQ cleaned forceps, wiped with paper towel.

2.5.3. Analysis QA/QC

Blank Whatman GF/D (2.7 μm) filters were exposed at all times during microscopy. Although the samples themselves were covered while not directly being examined, establishing baseline deposition contamination during microscopy analysis was prudent.

Particles were collected immediately prior to pyrolysis analysis and deposited into the pyrolysis sample cups under microscopy, confirming particle discharge from the forceps into the cup and correct placement for analysis. Samples were covered with aluminium foil during the physical transfer to the automatic sampler and while loading the samples. The pyrolysis unit itself also features a plastic guard which protects samples from atmospheric deposition during the duration of processing time.

3. Results

3.1. QA/QC results

Contamination during microscopy varied between 0 and 8 particles, averaging across all room blanks, procedural blanks and samples to be 2.6 ± 2.5 (95% CI) fibres of various colours. No blue fibres were detected while analysing the room blank, 0.4 ± 1.1 blue fibres were detected while analysing the procedural blank and 1.7 ± 2.2 blue fibres were detected while analysing the sample. This is considered to be negligible compared to the average number of blue fibres (8.8 ± 8.54 fibres) in the procedural blank and in the sample (58 ± 60 fibres), and therefore no baseline subtraction of contamination during analysis was undertaken. Contamination during microscopy consisted of particles which were 87% fibre shaped and 14% fragments, with the most dominant colour being black. Over 70% of the contamination particles were < 50 μm in size. The size fractions and colour characteristics of the contamination is detailed in Figs. S1 and S2 of the SI.

3.2. Air concentration

The number of blue particles on the analysed quarter of each sample was 1.6 ± 2.5 fibres in the room blank, 2.2 ± 2.3 fibres in the procedural blank and 14.6 ± 16.96 in the sample (Fig. 1).

Extrapolated to whole filter calculations, the room blank contained 6.4 ± 10.3 blue fibres, 8.8 ± 9.6 blue fibres in the procedural blank and 58.4 ± 67.9 blue fibres in the sample.

An ANOVA grouping the room blank and procedural blank against the sample demonstrated an f statistic of 8.9 and a p value = .01,

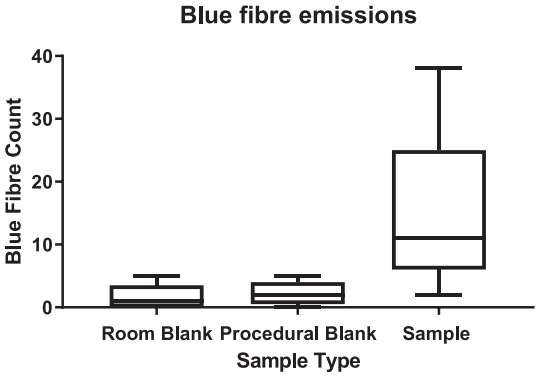

Fig. 1. Counts of blue particles per sample type. *Box indicates 25th and 75th percentiles, line is the median and whiskers represent minimum and maximum values. *Procedural Blank is the operation of the empty dryer without the blanket sample.

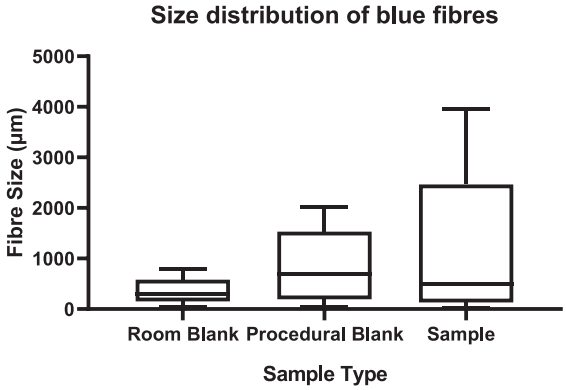

Fig. 3. Blue fibre size comparison between sample types.

indicating with statistical significance that the blanket emits microplastic fibres into the airborne environment.

3.2.1. Particle concentration in the air

Normalised against the operation of the sampler, the number of blue fibres in the air was calculated to be 0.17 ± 0.27 fibres/m^3 in the room blank, 0.5 ± 0.5 fibres/m^3 in the procedural blank and 1.6 ± 1.8 fibres/m^3 in the sample. (Fig. 2).

3.3. Air Particle Characterisation

3.3.1. Size classification

All blue particles detected were fibre shaped. The length of the blue fibres varied from 43 to 799 μm in the room blank (average 341 ± 273 μm), 47–2016 μm (average 844 ± 819 μm) in the procedural blank and 19–3948 μm (average 764 ± 940 μm) in the sample (Fig. 3).

3.4. Particle counts and consecutive laundering

The number of blue fibres in the atmosphere increased over consecutive laundering. No stability of fibre release was reached over time from five replicates. This is in contrast to Pirc et al. (Pirc et al., 2016), who demonstrated that shedding of a PET blanket during laundering and mechanical drying (captured lint in inbuilt filtration) decreased over consecutive laundering, reducing substantially post wash 3 to account for new garment shedding and stabilising after wash 7. Carney Almroth et al. determined that aged garments shed more fibres than new garments. However, overall shedding of fibres from PET fabric during laundering decreased over time, reaching stability for one type of PET weave after wash 5 whilst no stability was reached for a second PET weave after 10 washes (Carney Almroth et al., 2018). Hernandez et al. found that laundered PET fabric released decreasing amounts of microplastic fibres, stabilising after wash cycle 3 to 4 depending on laundry surfactant (Hernandez et al., 2017). It is unknown what attributed to the increased shedding of fibres into the atmospheric environment in these results. It is hypothesised that the increase of fibres into the air could be a result of degradation of the fibre from mechanical drying, possibly from the physical abrasion of the fabric within the internal drum of the dryer during rotation or the weakening of the fibres from the heat generated internally whilst mechanically drying the blanket. The cause remains unknown as does the impact of repeated laundering past 5 replicates, which should be examined further in future research. (Fig. 4).

3.5. FTIR analysis

FTIR characterised the blanket as poly (1,- cyclohexanedimethylene terephthalate) with 80% and 78% accuracy (Fig. S3) prior to processing, and poly (1,- cyclohexanedimethylene terephthalate) with 80% accuracy (Fig. S4) for the inbuilt dryer filter contents. Examination of randomly selected visible individual blue fibres proved unsuccessful based on difficulties ensuring correct placement of the particle for examination and library comparisons of very low accuracy.

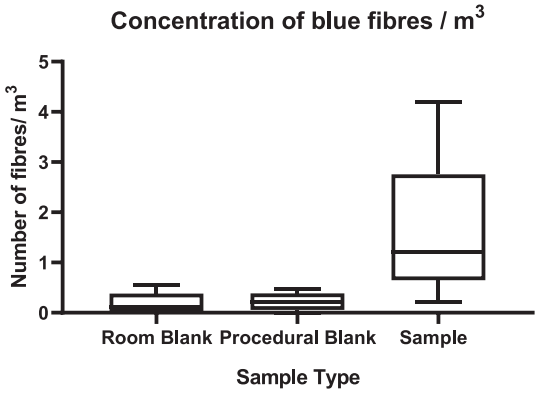

Fig. 2. A) Quantification of blue fibres per cubic metre (m^3) based on sample type. *Procedural Blank references the operation of the empty dryer without the blanket sample.

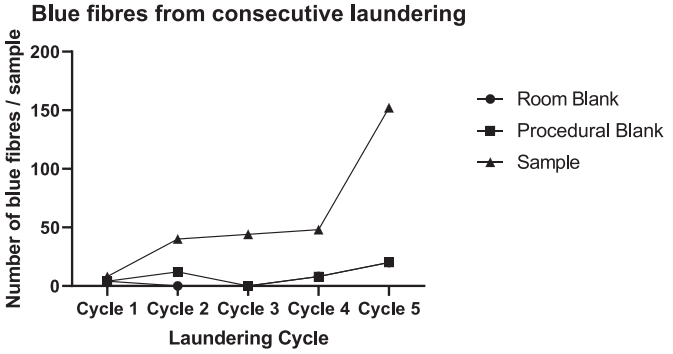

Fig. 4. Blue fibre emissions from consecutive laundering. *Extrapolated whole of filter calculations. Chemical and visual characterisation of material and fibre composition.

3.6. Pyr-GC/MS analysis

Fibres from the blanket that were unlaundered; washed and oven incubated at 60 °C for 20 min, along with pools of three to six individually picked blue coloured fibres from the samples to determine if they originated from the blanket fibres. Pyrograms from the blankets demonstrated consistent peaks in the chromatograms between replicates in total ion chromatograms (TIC) and indicator compounds/ions regardless of laundering effects. The chemical composition of the blanket was identified to be polyethylene terephthalate (PET) based on the presence of benzene, vinyl benzoate and benzoic acid. Insufficient indicator compounds were present for the positive identification of Poly (1,-cyclohexanedimethylene terephthalate), identifying discrepancy between FTIR and Pyr-GC/MS. Pyrograms following oven exposure for 20 min at 60 °C were consistent with PET. Pyrograms of pools of blue fibres indicated a PET composition in two replicates. All pyrograms are presented in the Supporting Information (Figs. SI 5–SI 7).

3.7. Microfibre emissions from mechanical drying captured by inbuilt filtration

Drying one 660 g polyester blanket generated 77 ± 22 mg of lint which equates to ~$1.1 \pm 0.3 \times 10^6$ fibres into the inbuilt filter. This is approximately 0.012% of the blanket mass. Additionally, 54 ± 60 fibres would be released into the air. It is noted these calculations have many associated uncertainties and assumptions, including that the per fibre weight is the same as that used in the calculations by de Falco et al. (De Falco et al., 2018) of 7×10^{-8} g/fibre: 6×10^6 to 17.7×10^6 fibres corresponding to a lint weight of 0.43–1.27 g of lint = 1.27 g/$17.7 \times 10^6 = 7 \times 10^{-8}$ g/fibre. Inherent variability in dryer emissions also exists regarding dryer characteristics such as different load capacities/venting options and different shedding propensities of the load composition and fabrics based on manufacture differences and fibre characteristics. As such, future estimates of microplastic emissions from laundering of synthetic materials should include drying as an emission source, however emission amounts require refinement and further research.

4. Discussion

Airborne emissions of 58 ± 60 fibres per 660 g blanket sample were higher than the amount of blue fibres present in the ambient air, being 6.4 ± 9.21 fibres. Subtracting the room blank and procedural blank values, mechanical drying contributes ~2 fibres/m^3 into the surrounding atmospheric environment. Working from the average of 58 fibres/660 g blanket, drying 1 × 660 g blanket/once per week (consistent with Australian dryer operation (Australian Bureau of Statistics, 2008b; Australian Bureau of Statistics, 2011)) could emit 3×10^3 airborne fibres into households and/or the atmospheric environment per household, per annum. A whole 6.5 kg polyester blanket load (being 6.5 kg wet weight capacity/average blanket wet weight of 830 g = 7.8 blanket capacity per drying load) could emit 406 ± 468 airborne fibres/load operated with exclusively polyester blankets. These figures do not consider discretionary dryer usage, differences in fabric, variability in usage both nationally and internationally or mechanical variations between dryer types.

As many of these fibres escape inbuilt filtration or are released when cleaning the filter (Cheng et al., 2016), human health implications should also be considered and examined. When vented indoors, these fibres are likely to accumulate in dust and contribute to microfibre abundance being reported in dust, as well as exposure via dust. Dryer placement within the household, clothing composition and frequency of use are expected to vary between countries. In Australia, 56% of households own a mechanical dryer and operate their dryer once per week (Australian Bureau of Statistics, 2008b; Australian Bureau of Statistics, 2008a), however frequency of operation would vary nationally, with differing climates. Dryer ownership and operation frequency also varies internationally. For example, in 2018, 58% of UK households owned a dryer and in 2017, 42% of households in Germany. In some countries such as the UK, the dryer is located within or adjoining the kitchen (Wendy Wills et al., 2013) which could potentially increase human exposure to airborne particulates and/or result in deposition onto food (Catarino et al., 2018) and food preparation surfaces, providing another avenue of human ingestion exposure as well as respiratory exposure.

5. Conclusion, limitations and future work

The major limitations of this work are the small sample size, the examination of one type of polyester blanket and one type of domestic dryer. Limitations also include the inability to calculate mass loss of the blanket and mass of the airborne fibres/filters, making gravimetric mass balance unachievable. Calculations of fibres per m^3 are approximate, based on variability of the air volumes sampled. Drying time was limited during treatments to the first 20 min of the cycle in consideration of room capacity to avoid over sampling the air. Retained water could have impacted the mass based outcomes.

Future work is required to gain an understanding of airborne dryer emissions, including the influence of technical specifications such as dryer composition (condenser/vented), temperature, RPM variability, textile materials or their length and weave composition impact on the prevalence of emissions into the environment (De Falco et al., 2018), as well as considering general laundry load composition or commercial laundromat emissions. These specifications could be applied into lifestyle or policy adaptations to reduce environmental and human exposure to microplastic fibres.

CRediT authorship contribution statement

Stacey O'Brien: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. **Elvis D. Okoffo:** Validation, Writing - review & editing. **Jake W. O'Brien:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing - review & editing, Software, Supervision. **Francisca Ribeiro:** Methodology, Writing - review & editing. **Xianyu Wang:** Methodology, Validation, Formal analysis, Writing - review & editing, Supervision. **Stephanie L. Wright:** Methodology, Validation, Writing - review & editing, Supervision. **Saer Samanipour:** Data curation, Formal analysis, Software, Writing - review & editing. **Cassandra Rauert:** Data curation, Investigation, Methodology, Validation, Writing - review & editing, Supervision. **Tania Yessenia Alajo Toapanta:** Conceptualization, Writing - review & editing. **Rizsa Albarracin:** Writing - review & editing. **Kevin V. Thomas:** Conceptualization, Funding acquisition, Methodology, Formal analysis, Resources, Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.141175.

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